

Information about

SILASTIC[®] BRAND

silicone rubber

SILASTIC 55U Silicone Rubber

Silastic[®] 55U silicone rubber is a high performance silicone rubber specifically designed for aircraft and aerospace seal applications. It offers greatly improved resiliency, abrasion resistance, toughness, low compression set, oil resistance, excellent processing, and reproducible properties in fabricated parts.

Silastic 55U rubber features elongation and tensile and tear strengths comparable to the best silicone rubbers. It will return instantly and completely from a stressed position with little loss of energy, giving

excellent sealing action. Light tan in color, the Silastic 55U rubber base is easily pigmented to almost any desired shade.

A versatile compound, Silastic 55U silicone rubber is easy to process and is suitable for a wide range of applications, including molded, calendered or extruded seals for aerospace uses. Typical applications include seals on access doors, hatches, bomb bay doors, windows, and other exterior openings in aerospace systems.

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications

As Supplied

Color Light Tan; pigmentable
Specific Gravity..... 1.17

As catalyzed with 1.5 parts of Cadox TS-50 per 100 parts of Silastic 55U stock, by weight; press molded on 0.075-inch-thick slabs for 5 minutes at 240 F, and oven cured 4 hours at 400 F.

ASTM D 746	Brittle Point, degrees F	-115
ASTM D 676	Durometer Hardness, Shore A Scale	50 ± 5
ASTM D 412	Tensile Strength, psi	1290
ASTM D 412	Elongation, percent	550
ASTM D 624	Tear Strength, ppi	170
ASTM D 624	Tear Strength, ppi at 212 F	135
ASTM D 1630	Abrasion Resistance	800
	Linear Shrinkage, percent	3.0
	Resiliency	
	Bashore, percent	50
	Tension Set, percent	7
	Bend Set, degrees	3
ASTM D 395	Compression Set, percent	
	After 70 hours at 77 F	5
	After 70 hours at 212 F	18
	After 22 hours at 350 F	38

(Continued on next page) ➡

The information and data contained herein are based on information we believe reliable. You should thoroughly test any application, and independently conclude satisfactory performance before commercialization. Suggestions of uses should not be taken as inducements to infringe any particular patent.

DOW CORNING

BULLETIN: 09-155

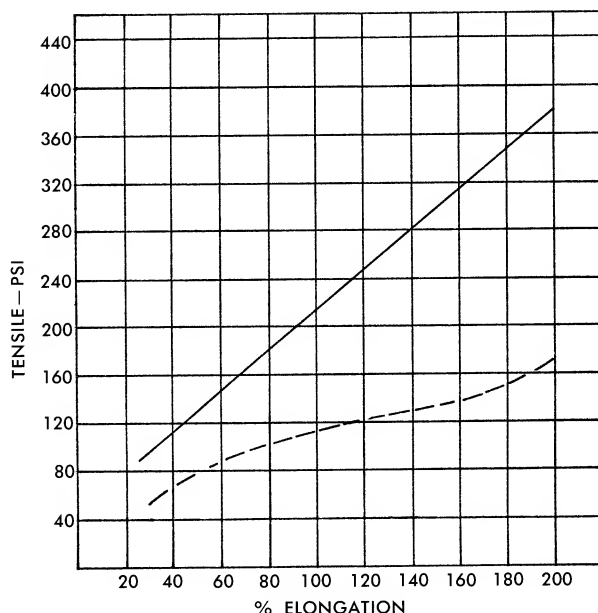
DATE: AUGUST, 1965

**ENGINEERING PRODUCTS DIVISION
DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48641**

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK

TENSILE MODULUS

Previous high tear strength silicone rubbers exhibit plastic flow at low elongations, as shown by the dotted line in the illustration. The straight line or true elastomer modulus of Silastic 55U silicone rubber provides instant recovery after deflection and positive sealing action.



EFFECTS OF HEAT AGING

To measure the effect of heat aging upon physical properties, vulcanized slabs of Silastic 55U rubber were prepared by standard procedures. These vulcanized specimens were oven cured for 4 hours at 400 F, and then were given the extended heat aging indicated in the table.

	Heat Aged for			
	70 hours at 212 F	24 hours at 392 F	70 hours at 392 F	24 hours at 437 F
Durometer Hardness Change, points.....	nil	+2	+3	+2
Tensile Strength Change, percent	-5	-5	-16	-13
Elongation Change, percent	-6	-9	-26	-18
Tear Strength, ppi.....		170	160	160

STORAGE LIFE OF UNVULCANIZED STOCK

Containers in which Silastic 55U silicone rubber are shipped carry a "Use before (month/year)" statement. This date indicates the period within which the stock should be processed to obtain good handling characteristics and best physical properties in the finished parts.

For Silastic 55U silicone rubber, the date listed is approximately four months from the date of shipment.

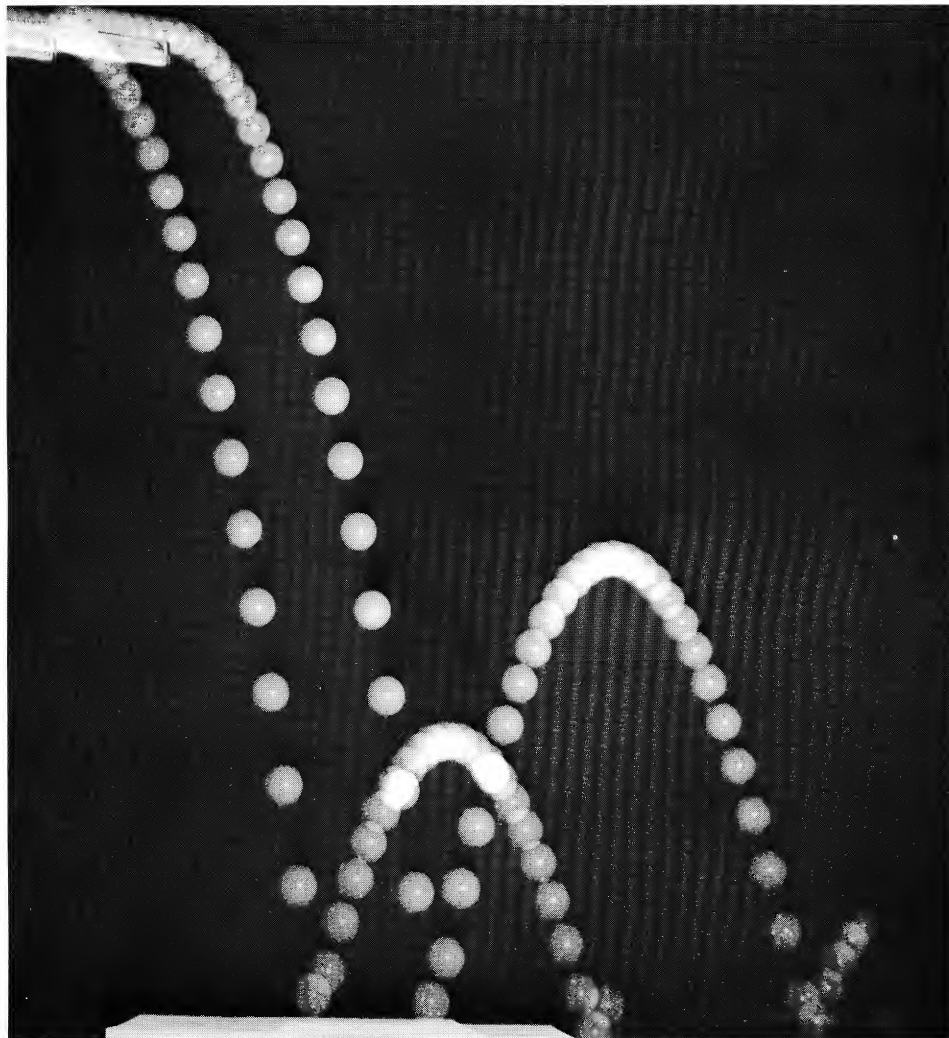
RESISTANCE TO EFFECTS OF OIL IMMERSION

Some military and commercial specifications require good resistance to the effects of immersion in certain fluids. Two of these fluids are ASTM No. 1 Oil, a low-swelling petroleum base oil, and Skydrol 500A, a phosphate ester hydraulic fluid. Typical changes in physical properties caused by immersion in these materials, under standard test conditions, are shown in the table.

	<i>ASTM No. 1 Oil, 70 hours at 300 F</i>	<i>Skydrol 500A, 70 hours at 160 F</i>
Durometer Hardness Change, points.....	-6	-8
Tensile Strength Change, percent	-10	-10
Elongation Change, percent	-10	+6
Tear Strength, ppi.....	...	150
Volume Change, percent.....	+5	+9

SHIPPING

Silastic 55U silicone rubber is supplied in 5 lb. and 50 lb. containers.



Superimposed photo of steel ball rebounding from Silastic 55U silicone rubber (at right) demonstrates its excellent resiliency over that of best previous high-strength silicone rubber (at left).

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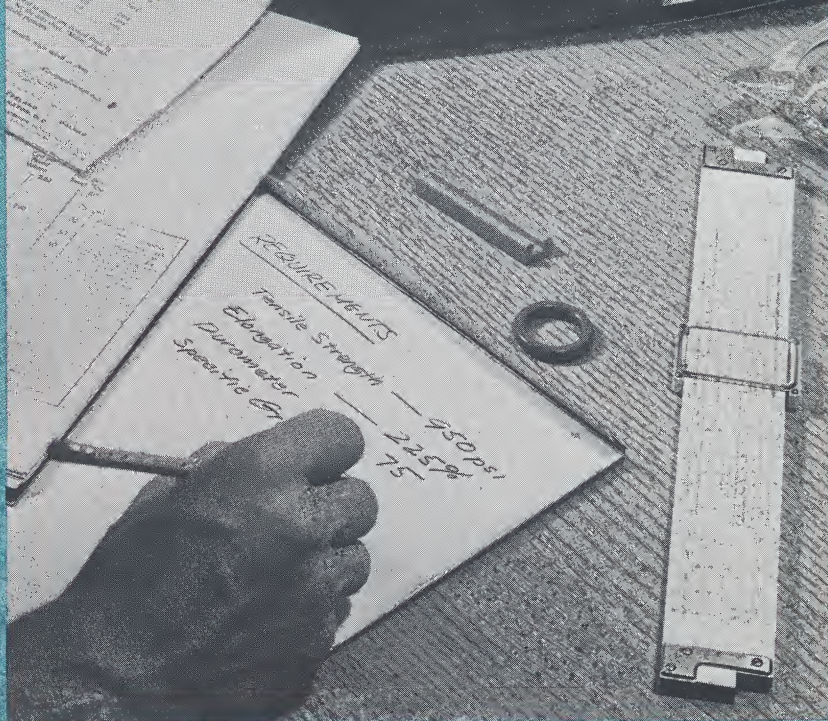
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Engineering with **SILASTIC[®]** BRAND Silicone Rubber

DOW CORNING

SILASTIC® Silicone Rubber

Silastic® brand silicone rubber is among the most stable elastomers known. It retains flexibility in extremes of temperature (–130 to 500 F), in corona and ozone atmospheres, in moisture and steam, in oil and after prolonged weathering and aging. Special grades—fluorosilicone rubbers—provide resistance to fuels and chemicals. These inherent properties of Silastic rubber compounds define elastomers that operate

reliably in environments that are often termed “rubber killers”.

The arbitrary properties of Silastic rubber—hardness, tensile strength, elongation, tear strength, compression set—can be selected according to the specific Silastic compound. There are over 50 such compounds, each with specific arbitrary properties. The inherent properties are approximately the same for all.

What is SILASTIC Rubber?

SILASTIC is the registered trademark of Dow Corning for its brand of silicone rubber. Chemically, silicone rubber is made up of a polysiloxane polymer and various reinforcing fillers. The polymer has a basic backbone composed of alternating silicon and oxygen atoms—a chemical structure very close to sand and rock. Organic chemical groups are attached as side chains to the silicon atoms. The arrangement and types of organic groups account for the differences between classes of Silastic rubber compounds, but it is from the silicon-oxygen chain that all silicone rubber compounds derive their inherent properties.

Silastic silicone rubber is supplied to rubber companies as a raw material, an amorphous solid in appearance. Consistency of the raw product ranges from pourable fluids through spreadable pastes to a relatively firm, dough-like material. These many grades allow processing by standard rubber equipment and by many specialized types of forming equipment. Finished products include O-rings, seals, gaskets, tapes, mechanical goods, sponge, coated cloth, and wire and cable insulation. Over 100 manufacturers of rubber parts produce finished goods made of Silastic silicone rubber.

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Types of SILASTIC Rubber

Silastic silicone rubber compounds are grouped in two ways—by polymer type, and by performance characteristics.

Polymer classification, described in ASTM D 1418, is based upon the organic group side chains attached to the silicon-oxygen chain. A polymer labeled simply Si indicates a chain with only methyl groups attached. If other groups are present, their initials are listed prior to the silicone designation. "P" indicates phenyl groups; "V"—vinyl groups; "F"—fluorine-containing groups. Thus, a stock described as PVS_i is a silicone elastomer having methyl, phenyl, and vinyl-containing side groups on the silicon-oxygen chain.

The compounds are divided into seven types according to performance characteristics, as shown in the following listing. The polymer types most often found in each performance group are shown in parentheses.

- (1) General purpose (VS_i or Si)
- (2) Extreme high temperature service (600 F) (VS_i or Si)
- (3) Extreme low temperature service (−130 F) (PVS_i or PS_i)
- (4) Low compression set (VS_i)
- (5) High tensile; high tear strength (PVS_i)
- (6) Oil and fuel resistant—fluorosilicone rubbers (FVS_i)
- (7) Food Grade—FDA-approved ingredients (all polymer types)

Major points of the seven basic types of Silastic compounds are summarized as follows:

- (1) *General purpose* stocks are produced in hardnesses ranging from 40 to 90 Shore A durometer points, with tensile strengths ranging from about 400 to 900 psi and ultimate elongations of 60 to 300 percent. Recommended continuous service temperature ranges for these stocks extend from about −70 to 500 F. General purpose stocks have good dielectric characteristics, and are not significantly affected by contact with many fluids and oils. Resistance to effects of immersion is, of course, dependent on type of fluid and exposure conditions. A complete discussion is presented on pages 8 and 9.
- (2) *Extreme high temperature service* stocks withstand continuous operating temperatures of 600 F for a much longer period of time than general purpose stocks. This extra high temperature stability is gained by the use of special additives. Physical properties of high temperature stocks are similar to those of the general purpose stocks, when both are tested at room temperature.
- (3) *Extreme low temperature service* compounds are flexible at temperatures as low as −130 F. The temperature at which these stocks become brittle is as low as −180 F, compared to a brittle point of about −100 F for general purpose compounds. Other properties of low temperature grades are generally comparable to those of general purpose compounds, though oil resistance is not quite as good.

- (4) *Low compression set* compounds excel in an area where all silicone rubber stocks are inherently strong—resistance to permanent deformation when held in compression for long periods at elevated temperatures. Measured after compression for 22 hours at 300 F, most general purpose stocks exhibit a set of less than 25 percent; by comparison, the special low-set compounds have values of 7 to 15 percent after 70 hours at 300 F, and 50 percent or less after 22 hours of compression at 480 F.

Other physical properties of low-set Silastic rubber compounds are quite similar to properties of general purpose stocks; exceptions for the low set compounds are their somewhat improved resistance to petroleum oils and hydraulic fluids, and slightly lower elongation values.

- (5) *High tensile; high tear* grades of Silastic silicone rubber have tensile strengths in the range of 1100 to 1700 psi, and tear strength values of 175 to 250 pounds per inch. By comparison, general purpose stocks have tensile strengths up to 1000 psi, and tear strength values normally ranging from 40 to 80 pounds. The rubberiness of these high strength stocks is further demonstrated by ultimate elongation values which range from 500 to 700 percent.
- (6) *Oil and fuel resistant* stocks are the fluorosilicones. These stocks are designed for use where contact with jet fuels, aromatic solvents, gasoline or crude oil (which swell general purpose silicone rubbers) is required. Fluorosilicones are serviceable over a temperature range of −80 to 350 F in contact with fluids, and up to 450 F in dry heat. Other physical properties are comparable to those of general purpose compounds.
- (7) *Food grade* silicone rubber stocks are those made up entirely of ingredients which are listed by the Food and Drug Administration in 21 CFR 121.2562 under which those ingredients may be present in a rubber used in the production, packaging and storage of food products as long as the applicable limitations upon extractives for the particular foods as set forth in that regulation are met.

Tabulation of representative property data for any type of rubber is always difficult because of the number of variables involved in compounding and processing rubber. Given a set of performance requirements, the rubber parts manufacturer will choose a Silastic rubber stock that best meets the requirements. By modifying the compound with additional filler or by adjusting processing procedures (i.e., cure time or temperature), the properties may be varied somewhat to meet specific individual requirements. Individual properties of any stock are interdependent; the improvement of one may result in the lowering of another. Thus, the design engineer must decide whether a *balance* of all properties is desirable or whether one property in particular should be emphasized, though this may mean a sacrifice in other properties. Knowing this, the parts manufacturer will recommend a Silastic rubber stock most closely suited, and then use processing techniques that will achieve the required performance specifications.

Serviceability Over a Wide Temperature Range

EFFECTS OF ELEVATED TEMPERATURES

Design problems that demand elastomers that stay rubbery after long exposure to elevated temperatures can often be solved by using parts made of Silastic silicone rubber.

Like other elastomers, silicone rubber shows two main types of change when exposed to elevated temperatures:

- (1) *Immediate effects*, occurring as soon as the rubber reaches a given temperature, and
- (2) *Heat aging effects*, which take place over longer periods of time.

Immediate Effects

All elastomers lose tensile strength and elongation as temperatures rise—sometimes very rapidly. For instance, a heat-stable natural rubber compound, with a tensile strength of over 3,000 psi at room temperature, may show only 15 to 18 percent as much strength at 300 F. By comparison, silicone rubber has modest properties at room temperature, but retains as much as 75 percent of its room temperature strength at 300 F.

All classes of silicone rubber retain a high percentage of original properties when heated, stay rubbery and flexible, continue to behave as elastomers. After the initial loss of strength, which takes place as the rubber reaches service temperature, there is a very gradual strength loss due to the effects of heat aging.

Long Term Heat Aging

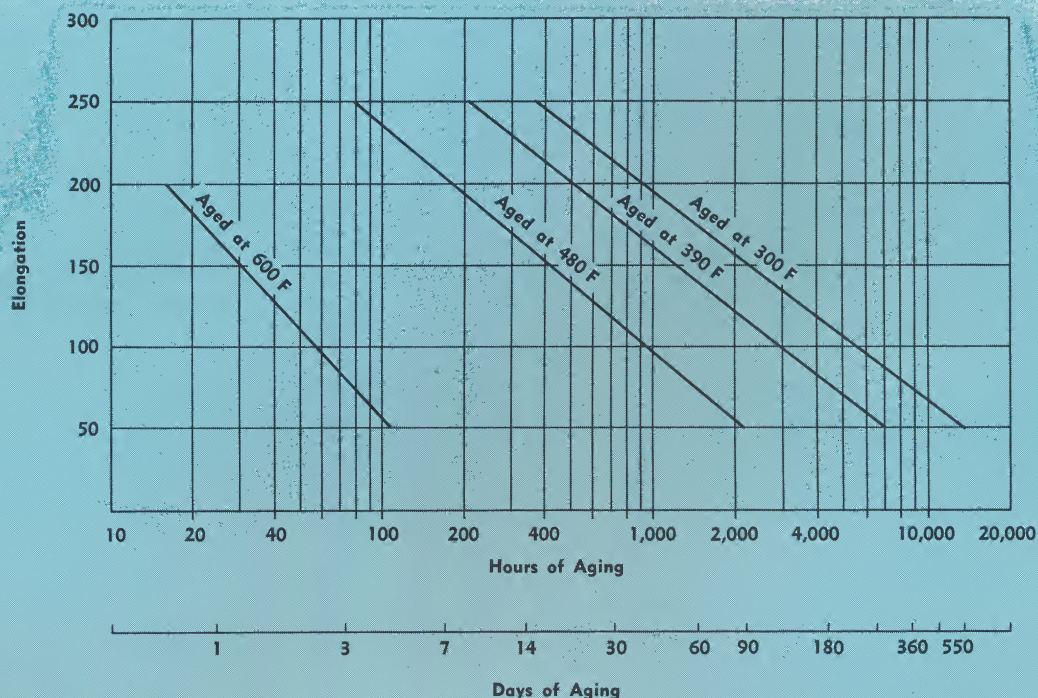
As silicone rubber is heat aged at temperatures from 300 to 600 F, it gradually hardens and loses its elasticity. However, certain properties may improve: resistance to compression set normally increases somewhat (when the sample is heat aged prior to compression), and the rubber may become a little more resistant to attack by oils and chemicals. Tensile strength shows various changes, depending on the stock being tested. It may decline slowly, remain fairly stable, or may even increase somewhat with continued heat aging.

Of all these properties, perhaps elongation, as a measure of "rubberiness", gives the best indication of the overall change in properties in a silicone rubber with heat aging. Figure 1 shows this relationship.

TABLE I—PROPERTIES AFTER HEAT AGING AT 700 F

Minutes at 700 F	Hardness, Shore A Scale	Tensile Strength, psi	Elongation, Percent
0	53	890	275
5	45	600	300
10	40	325	290
15	40	130	100

FIGURE 1.
Effects of
Heat Aging
on Elongation
at Various
Temperatures



Effects of Very High Temperature

At temperatures above 600 F, the typical pattern of heat aging changes. Elongation may not decline as fast as the tensile strength of the rubber. Hardness, which normally increases with aging at moderate temperatures, may actually drop with aging at very high temperatures. These effects are shown in Table I. These values were obtained from tests on a 50-durometer Silastic stock compounded for maximum heat stability.

Effect on Compression Distortion

When an elastomer is compressed and then released, it returns to its original shape. However, as the compression time is increased, the rubber begins to take a "set"—that is, it does not return to its exact original shape. If this set or distortion becomes too great, the dimensional change renders the part unfit for its original purpose. For example, a seal that has been distorted in this manner may no longer perform as a good seal; leakage can occur. At high temperatures elastomers take on this "set" more rapidly than at room temperature.

This distortion is measured and defined in a test for compression set (ASTM D 395). Silastic silicone rubber has an inherently low room temperature compression set—but more importantly maintains this low set at high temperatures.

If low temperature (below -50 F) compression set is a problem in a particular application, it is best to choose a Silastic stock designed especially for extreme low temperature service. Table II compares typical compression set values for general purpose, fluoro-silicone, and extreme low temperature Silastic rubber stocks, after compression at a temperature of -65 F.

**TABLE II—COMPRESSION SET AT -65 F
AFTER 22 HOURS**

Type of Stock	Percent
Si (general purpose)	100
FVSi (fluorosilicone)	100
PVSi (extreme low temperature)	25 to 50

Figure 2 compares the compression set of general purpose Silastic rubber and one of the compounds of the low compression set type, after compression for 22 hours at various temperatures.

FIGURE 2.
Samples Compressed 22 Hours at Temperature
(Method: ASTM D 395)

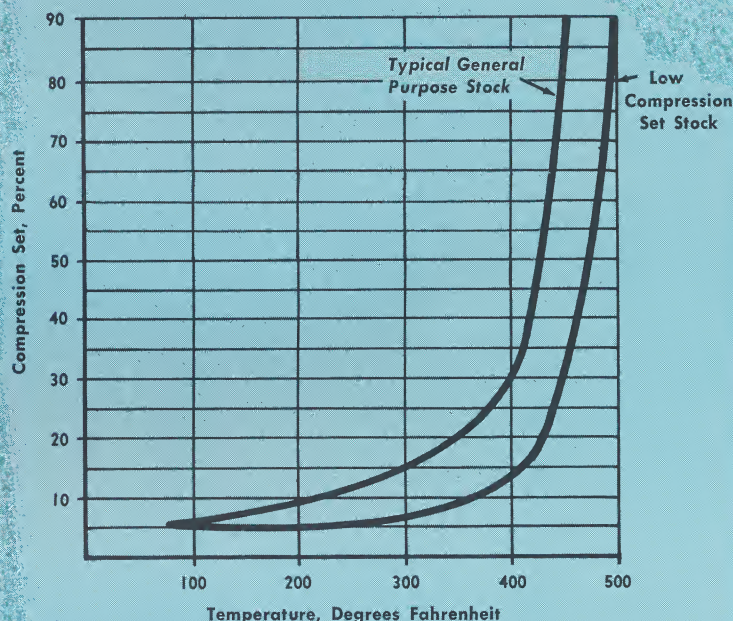


FIGURE 3.
Compression Set vs. Time Under Compression

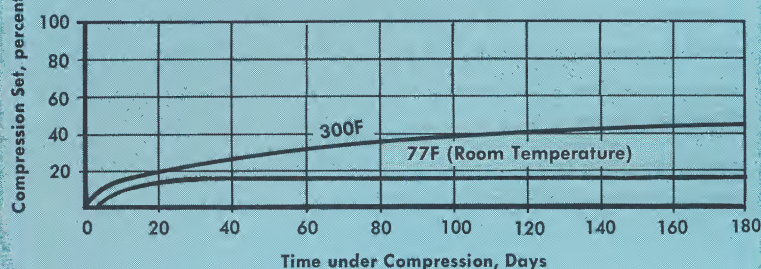


Figure 3 depicts the compression resistance of Silastic rubber as related to time under compression. This graph emphasizes the resistance offered to long-term compression set at high temperatures. It shows that, as a gasketing material, silicone rubber may be expected to retain a resilient sealing action for long periods of time, even at temperatures of 300 F.

Correlation of Test Results, Service Life

Heat aging tests are very helpful in comparing different silicone rubber compounds, especially if testing is carried out at service temperatures. However, it is sometimes hard to predict service life of a silicone rubber on the basis of such tests. Service temperatures may fluctuate from hour to hour, or even minute to minute, and often a part is hotter at one point than at another. In a hot air duct, for example, the air in the interior may register a temperature of over 600 F. The exterior of the duct, on the other hand, may be operating in ambient temperatures as low as -65 F.

When such situations are encountered, it is usually best to select a rubber known to give good performance in similar applications, and conduct preliminary tests under conditions simulating actual service.

Confinement Shortens Service Life

When silicone rubber is heated in close confinement (as, for instance, in a tight metal box or under a large metal flange), it may exhibit reversion, particularly if heated at temperatures above 400 F. Reversion is a condition characterized by softening, loss of tensile strength, and high compression set. These changes in properties take place much more rapidly under these conditions than do changes from heat aging.

To avoid the effects of reversion, it is advisable to design units and rubber parts so that at least a portion of the rubber surface is exposed to the outside air, and to cure the part prior to confinement at a temperature at least 50 degrees above the anticipated service temperature.

OTHER THERMAL PROPERTIES

Thermal Expansion

The coefficient of volumetric thermal expansion for all Silastic rubber stocks is in the range of 3.3 to 4.4×10^{-4} per degrees F, or 5.9 to $7.9 \times 10^{-4}/^{\circ}\text{C}$. The linear coefficient of thermal expansion is roughly one-third of the volumetric coefficient of thermal expansion and can be used to calculate the total linear thermal expansion of a rubber part over a temperature range. For example, if the volumetric coefficient of thermal expansion is 5.9×10^{-4} per $^{\circ}\text{C}$ and the temperature span in question is from 0°C to 150°C the total linear expansion of a part 1 inch long would be

$$\frac{5.9 \times 10^{-4} \times 150^{\circ}\text{C} \times 1 \text{ inch}}{3} = 0.0295 \text{ in.}$$

Specific Heat

Specific heat ranges from 0.30 to 0.35 BTU/LB $^{\circ}\text{F}$. The same values apply if measured by cal/gr/ $^{\circ}\text{C}$. Generally, the higher hardness stocks—60 or more

durometer points—are at the low end of this scale; lower hardness stocks are at the high end.

Thermal Conductivity

Compared with most other elastomers, Silastic silicone rubber stocks have relatively high thermal conductivity. Values usually range from 1.1 to 1.5 BTU/hr/sq/ft/ $^{\circ}\text{F/in}$, or 0.378 to 0.515×10^{-3} gr-cal/sec/cm 2 /cm/ $^{\circ}\text{C}$.

EFFECTS OF EXTREME LOW TEMPERATURES

No permanent change occurs in the physical structure of silicone rubber after exposure to low temperature. Original physical properties are regained when the rubber is brought back to room temperature. More important, however, silicone rubber stays flexible at temperatures that cause most elastomers to become brittle and crack if flexed.

It is the polymer used in a compound which determines its low temperature behavior; therefore, Silastic rubber compounds can be classified according

FIGURE 4.
Gehman Flexure of
SILASTIC Rubber vs. Temperature
(ASTM D 1053)

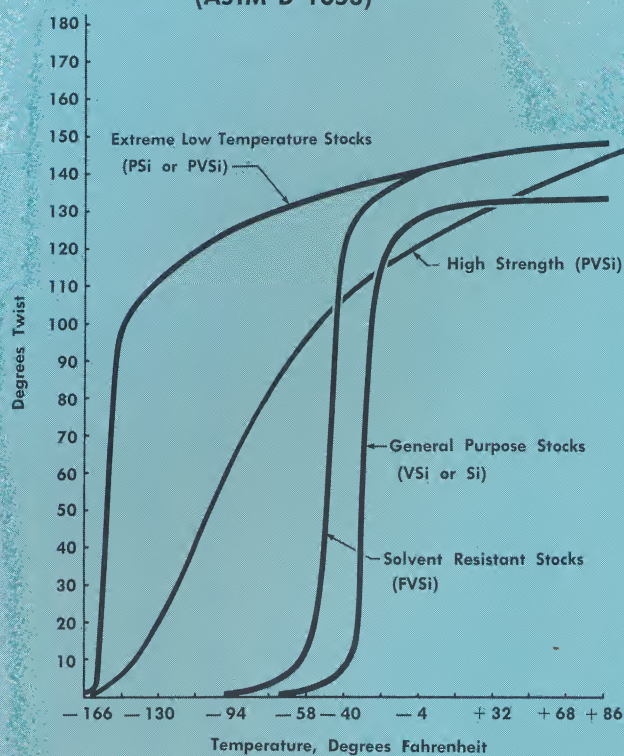


TABLE III—COMPARISON OF STOCK

Type of SILASTIC Rubber Compound	Brittleness Temperature by Impact ASTM D 746	Stiffening Point Young's Modulus in Flexure ASTM D 797
General Purpose.....	–100 F	– 65 F
Solvent Resistant.....	– 90 F	– 75 F
Extreme Low Temperature	–175 F	–165 F

to the low temperature characteristics of the four principal polymer types:

- (1) General purpose stocks—VSi (or simply Si)
- (2) Solvent-resistant stocks—FVSi
- (3) Extreme low temperature stocks—PSi
- (4) High strength stocks—PVSi

There are three standard tests which are used to measure the low temperature characteristics of elastomers. These tests are:

- (1) Brittleness Temperature by Impact—ASTM D 746
- (2) Young's Modulus in Flexure—ASTM D 797
- (3) Gehman Flexure—ASTM D 1053

The low temperature properties of the four major divisions of Silastic rubber compounds, as measured by the Gehman Flexure Method are compared in Figure 4. Table III compares the stocks as tested by the other two methods.

Which Test To Use

Each test has a particular significance in relation to actual applications. In some cases, even a moderate stiffening of the rubber part will impair its usefulness. In other cases, the part may be required to retain only a small amount of elasticity. The brief descriptions that follow relate, in general, which test method is best for a given application.

Brittleness Temperature by Impact

The temperature at which Silastic rubber specimens become brittle is determined by an impact method. Strips 1¼-inch long are clamped at one end to a fixed support in the test machine, then cooled to successively lower temperature levels. After 10 minutes at each temperature, a solenoid-actuated pendulum strikes the samples at their free end. The "brittleness temperature" is reached when 50 percent of the specimens break.

Brittleness temperature for most general purpose stocks is about –100 F and for most extreme low temperature stocks about –175 F.

Young's Modulus in Flexure

In this test, a sample of rubber 1-inch wide, ¼-inch thick, and 2½-inches long is supported at each end, as a simple beam, and loaded with a measured weight at a point midway between the supports. The apparatus is enclosed in a cold chamber.

Starting at room temperature, the amount of bending is recorded at successively lower temperature levels. Specimens are held at each test temperature for 20* minutes before testing. This test period provides an "equilibrium" or "constant stiffness" reading.

Young's Modulus Flexure is calculated at each temperature according to the following formula:

$$E = \frac{Ll^3}{4 wt^3(R_2 - R_1)}$$

Where: E = Young's Modulus

L = load in pounds

l = distance between supports (inches)

w = width of specimens (inches)

t = thickness of sample

R₁ & R₂ = deflection readings

The temperature at which Young's Modulus reaches 10,000 psi is arbitrarily defined as "Young's Modulus Stiffening Temperature" in literature describing Silastic rubber stocks.

For general purpose stocks, this temperature is about –65 F and for extreme low temperature stocks about –165 F.

Gehman Flexure

This test measures the amount of twist produced in a specimen at various temperatures by a constant torque.

In conducting the test, a specimen (1½ x ⅛ x 0.085-inches) is clamped in place in the machine, and then cooled to a temperature of –202 F. A predetermined, constant torque is then applied to the specimen, and the resulting twist of the sample is recorded. The temperature is then raised in steps of 18 degrees Fahrenheit, testing at each step. When room temperature is reached, the process is reversed; the sample is cooled to successively lower temperatures, testing at each step.

Data are often presented graphically, as in Figure 4. In this particular test, the specimens were allowed to stand at each test temperature until the Gehman twist value became constant. The maximum time required for this equilibrium stiffness to be reached was about three hours.*

* In general, these conditioning periods are longer than those specified in the various ASTM methods. The longer periods are used in order to allow the silicone rubber to reach an equilibrium stiffness.

Resistance to Effects of Oils, Chemicals, Solvents

**TABLE IV—CHEMICAL AND OIL
RESISTANCE RATINGS**

Reagent	Percent Volume Change	
	Fluorosilicone Rubber Percent	Typical Range of All Other Silicone Rubber
ACID SOLUTIONS (tested 7 days at room temperature)		
10% hydrochloric acid	1	0 to 2
conc. hydrochloric acid ...	8	0 to 15
10% nitric acid	1	1 to 10
conc. nitric acid	4	-10 to -5 (some deterioration)
10% sulfuric acid	nil	1 to 5
conc. sulfuric acid	decomposed	
conc. acetic acid	21	5 to 18
ALKALI SOLUTIONS (tested 7 days at room temperature)		
10% ammonium hydroxide	nil	nil
conc. ammonium hydroxide	3	0 to 7
10% sodium hydroxide ...	nil	0 to 3
50% sodium hydroxide ...	1	0 to 9
SOLVENTS (tested 7 days at room temperature)		
acetone	180	15 to 25
carbon tetrachloride	20	over 150
ethyl alcohol	5	0 to 20
iso-octane	15	over 150
xylene	20	over 150
reference fuel B	22	over 150
jet fuel JP-4	10	over 150
OILS (tested 70 hours at 300 F)		
ASTM No. 1 Oil	nil	5 to 10
ASTM No. 3 Oil	4	35 to 60
MIL-O-7808 Oil (Turbo Oil No. 15)	10	10 to 30
Hydraulic Fluid MIL-O-5606 (Univis J-43)	10	over 150
Oronite 8200 (silicate ester)	6	over 150
Dow Corning 200 fluid, 100 centistokes (Silicone fluid)	nil	28 to 35
Skydrol 500 (phosphate ester) 70 hrs at 212 F	30	10 to 20

Silastic silicone rubber stocks are divided into three main groups, on the basis of fuel, oil, and solvent resistance, as follows:

- (1) *Fluorosilicone rubber stocks* (identified by the prefix LS, as in Silastic LS-53 silicone rubber)—excellent fuel, oil, and solvent resistance.
- (2) *All other Silastic rubber stocks*—good resistance to certain types of oils and solvents. (These stocks may be subdivided according to the amount of filler and the type of polymer they contain.)
- (3) *Blends*—blends of classes 1 and 2 show solvent resistance intermediate between the two types.

If a given solvent, fuel, or oil affects a silicone rubber, this effect will generally show up in the following ways: (1) swelling (2) softening and (3) loss of strength. These effects usually go hand-in-hand, although no quantitative relationship between those properties has been developed. As an example, one silicone rubber shows a 10 percent swell in a given solvent, with a 15 percent loss in tensile strength, while in another solvent the same rubber shows identical swell but the tensile drop is 30 percent. Thus, swell figures alone may not always give an accurate picture of the deterioration of a rubber.

Table IV gives ratings of various types of Silastic rubber stocks in various oils, fuels, solvents and chemicals. To aid in interpreting this information, several generalizations are given in the following paragraphs.

- (1) In most solvents, Silastic LS silicone rubber stocks are superior in solvent resistance to all other Silastic rubber stocks. Exception: in acetone and certain other ketones, and in phosphate esters, regular Silastic rubber stocks are better.
- (2) General purpose stocks are slightly more resistant to most solvents than are low temperature stocks (those with brittle points of -178°F).
- (3) Other factors being the same, high durometer stocks are generally somewhat more solvent resistant than low durometer stocks, since higher durometer materials usually contain more filler, which does not swell.

- (4) Solvent resistance normally improves as the curing time or temperature increases. However, the fluoro-silicone rubber stocks are an exception to this rule; usually no increase in solvent resistance is to be expected with either longer or hotter oven cures.
- (5) When immersed in concentrated solutions of strong oxidizing acids, some stocks show a shrink (negative swell). Concentrated solutions of sulfuric acid have a particularly powerful action, dissolving both silicone and fluorosilicone stocks.
- (6) These data given in Table IV are useful only as a comparison of the swell of these stocks. The best way to predict the utility of a stock in service is to test it under actual conditions.

Service Factors Influence Solvent Resistance

Immersion tests give an excellent picture of what happens to a silicone rubber . . . when immersed under controlled conditions in the laboratory. But in actual service, parts are often only partly immersed, or subject only to spillage or splashing. Also, other conditions may be entirely different from anything which can be duplicated within the framework of standard tests.

The most widely used test, ASTM D 471, emphasizes this limitation in the following words: "Owing to the wide variations often present in service conditions, no direct correlation between this accelerated test and service performance may be given or implied. However, the method yields comparative data on which to base judgment as to service quality and is especially useful in research and development work."

Swell Often A Limiting Factor

Swelling is probably the most noticeable effect which a solvent may have on a silicone rubber, and is often a limiting factor in actual service. Even so, a small amount of swelling may not be harmful, and may even be desirable. O-rings, for example, often work better if they swell slightly in the fluid they seal. But if they

swell a great deal, they may push themselves out of position and lose their effectiveness.

Swell and other solvent effects often proceed to a definite limit, and then increase no further. This limit corresponds to the maximum amount of solvent which can be absorbed by the rubber at that test temperature.

Temperature and Duration of Exposure Are Important

In general, the solvent resistance of a rubber decreases as the exposure temperature increases, and this is true for silicone rubbers, too. A solvent that produces very little effect at room temperature may cause a noticeable swell at 400 F.

Duration of exposure may be very important in some applications. Silicone rubber often recovers most of its original properties if allowed to dry out after exposure to a volatile solvent. In the case of silicone rubber used as electrical insulation, this may mean that no permanent harm will result from washing or rinsing, even with very active solvents.

As a matter of caution, if the part is restricted in a tight metal clamp, it may tear as it swells.

On long exposure at high temperatures, oils may slowly decompose and the resulting products can have an entirely different solvent effect than the original oil. Sometimes heating may be favorable, driving off more volatile constituents. In other cases, the breakdown products may be more destructive.

In the case of lubricating oils, contamination in service may also produce changes in solvent activity.

Test In Service

Although immersion testing will aid in selecting the best silicone rubbers for service trials, the most reliable way to find out how a silicone rubber will perform in a given application is to test it under actual service conditions.

Weathering Properties

Weather Resistance

The oxidative process of weathering has virtually no effect upon the physical properties of silicone rubber. Long exposure to ultra-violet, rain, snow or ice produces no cracking or checking. Weathering properties of Silastic silicone rubber were tested at sites in southern Florida (refer to Table V) and in north central Michigan. All samples were prepared and mounted as specified in ASTM Test Method D 518, which calls for specimens to be in a stressed condition during the test life. At both test sites (the one in Michigan is atop a three-story factory building) racks of samples faced south, and canted upward to catch the full impact of rain and sun.

Because no cracking or checking has developed on

any Silastic rubber specimens to date, an additional procedure has been set up to evaluate samples.

Periodically some strips are removed, cut into standard tensile bars and tested for tensile strength, durometer hardness, and ultimate elongation. This procedure is a severe test. In fact, it is regarded as too severe for most types of rubber, since even the smallest crack will start a tear and yield very low tensile strengths.[†] Silicone rubber can be successfully tested in this way only because it has superior weather resistance.

Table VI presents a summary of the change in physical properties noted in samples weathered for one to five years.

[†] See ASTM D 518.

TABLE V—VISUAL INSPECTION REPORT: SOUTH FLORIDA TEST STATION

Test No.	Test Samples*	Months Under Test	Sun Hours	Appearance as Viewed Under 10X Magnification
1.	Silastic rubber specimens	120	15,184	No visible changes
2.	Silastic rubber specimens	93	11,541	No visible changes
3.	Silastic rubber specimens	63	7,687	No visible changes except for traces of mildew on some samples. This may be growing in dirt film on the specimens.

* Conditioned by both Method A and Method B, ASTM D 518.

TABLE VI—CHANGE IN PROPERTIES OF WEATHERED SAMPLES

The following results were obtained from tests on eight different Silastic stocks. All samples were given oven cure recommended in the data sheets on these products. Test site: roof top, Midland, Mich.

	Samples Conditioned as in ASTM D 518					
	Method A			Method B		
	1 yr.	2 yrs.	5 yrs.	1 yr.	2 yrs.	5 yrs.
Hardness Change, points...	+3 to - 6	+2 to - 6	+ 8 to - 9	+1 to - 8	-3 to -16	+ 5 to - 8
Tensile Change, percent....	+8 to -25	+4 to -22	+22 to -27	0 to -23	-8 to -40	-14 to -54
Elongation Change, percent	0 to -30	+4 to +28	+14 to -34	+4 to -40	0 to -45	-24 to -50

Method B, in general, provides a more stringent weathering test than Method A. Similar results are obtained with the Florida test samples.

Effects of Ozone

To test resistance of silicone rubber specimens to the effects of ozone, test procedures outlined in ASTM D 518 and ASTM D 1149 were used with some modifications.

Specimens were stretched 20 percent, as specified in ASTM D 518; in addition to this static condition, a dynamic test was devised whereby the specimen was elongated 25 percent in a cycle of 30 stretches per minute. This cycling would, of course, result in rapid propagation of any cracks that might occur from the ozone.

Test method ASTM D 1149 was modified as follows:

- (1) Under procedure, part (c) specifies a concentration of 25 parts ozone per 100 million parts of air ...

this was increased to a concentration of 30,000 parts of ozone.

- (2) Part D states that a temperature of 90 F may be used for elastomers having low resistance to ozone cracking, and that 120 F is satisfactory for materials with good resistance... Silastic rubber was tested at 165 F.

For both static and dynamic tests, the results were:

- (1) No significant change in durometer hardness, tensile strength, or percent elongation for specimens tested after exposures of 2, 4, 6, and 8 hours;
- (2) No cracking or checking visible when viewed with 10X magnification.

Effects of Radiation

The general effects of radiation on silicone rubber are very similar to the effects of heat aging. As the total radiation dose is increased, these effects are produced:

- (1) Hardness of the rubber increases.
- (2) Tensile strength may go up at first, but later is much reduced.
- (3) Elongation goes down.

These effects are caused by:

- (1) Direct disruptive effect of the radiation itself. A fast moving electron (beta ray), for example, may break certain chemical bonds between atoms, and allow new combinations that result in an increased number of cross-links between elastomer molecules.
- (2) Heat produced by the absorption of radiation energy. At high levels of radiation, extremely high temperatures may occur momentarily in local areas of the elastomer. This likewise produces rapid molecular changes—and these changes become apparent as changes in the properties of the elastomers.

The direct effects of radiation are proportional to the total amount of radiation received, as long as the radiation level is low or moderate. However, at high radiation levels the heating effects cause additional changes to take place.

Combinations of environmental heat and radiation also produce a more rapid rate of change in materials than does radiation alone. For this reason, when comparing values for radiation resistance given in the

literature, it is necessary to make sure that all tests were run at the same temperature.

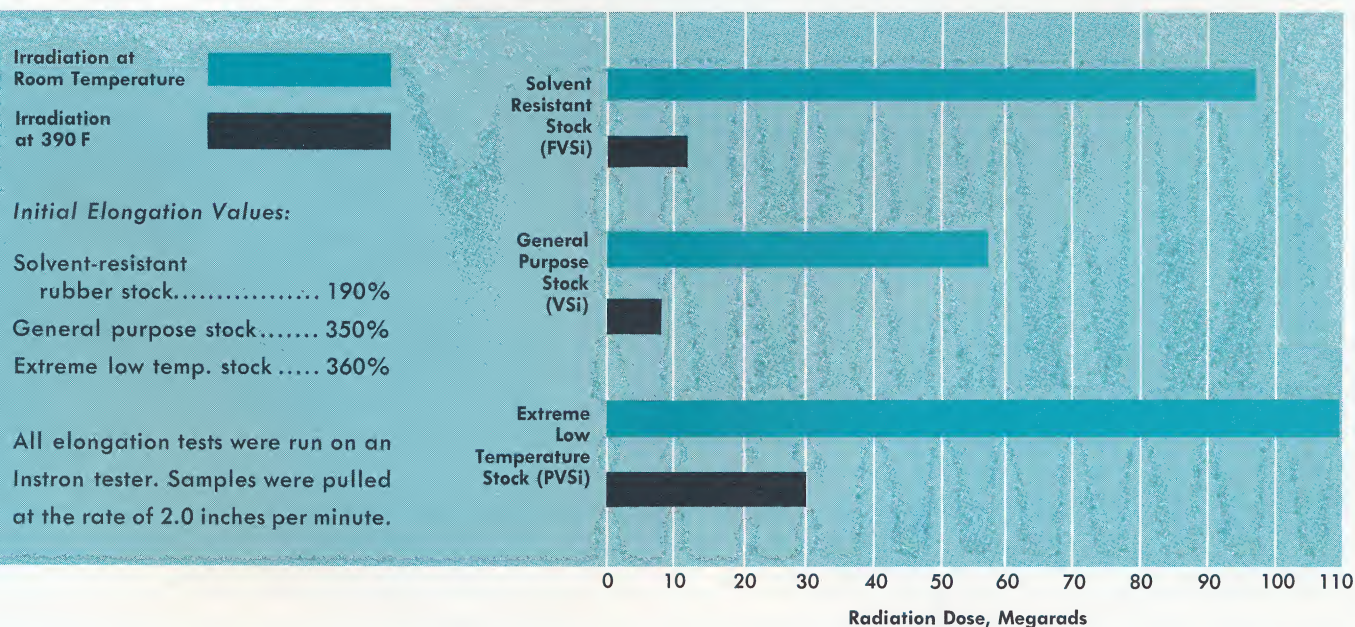
The effects of radiation on silicone elastomers is given in Figure 5. In general, elongation is inversely proportional to the logarithm of the radiation dose, and hence is a good indicator of the deteriorating effect of radiation. Figure 5 shows the radiation dose required to reduce the percent of elongation of several Silastic rubber stocks to an absolute level of 50 percent. Data are given for radiation exposure at room temperature and also at 390 F. The source of radiation was a cobalt-60 source, which emits gamma rays.

Different stocks had different initial elongations. In general, stocks with higher initial elongations will require higher amounts of radiation to reduce the elongation to 50 percent.

The level of 50 percent elongation was arbitrarily chosen as the end-point of the test because it represents, for some applications, the minimum amount of "rubberiness" that an elastomer can have and still be useful. Of course, static seals and similar products might remain serviceable at much lower levels of elongation.

Research into the problem of radiation resistance has shown that radiation resistance is related to the phenyl content of the silicone polymer used in producing elastomers. This effect can be seen for both temperatures of exposure; the stock with the highest radiation resistance is a silicone rubber stock which is compounded from a polymer of higher phenyl content than any of the other stocks listed.

FIGURE 5.
Radiation Doses Required to Reduce Elongation of Various Types of SILASTIC Rubber Compounds to an Absolute Value of 50 Percent.



Silicone Rubber as an Electrical Insulating Material

As an electrical insulating material, silicone rubber gives most of the benefits associated with common insulating materials—and some unique contributions of its own.

Like other elastomers, silicone rubber withstands vibration, flexing, and abrasion better than rigid insulating materials, and it is not prone to crazing or cracking.

Simple exposure to adverse environments such as heat, cold, moisture, oil, ozone, does not significantly change the electrical properties of silicone rubber. As with other elastomers, electrical failure occurs only when the environment destroys the physical integrity (by cracking, softening or deformation) of the insulation. Because silicone rubber withstands these environmental stresses physically, its electrical properties remain unchanged for longer periods of time than many other flexible insulating materials.

Electrical Properties of Silicone Rubber

There are five basic tests to evaluate the electrical properties of silicone rubber. These tests, based on specimens cured according to the manufacturers' recommendations and determined by ASTM test methods, present typical values as shown in Table VII.

Electrical properties of silicone rubber after prolonged heat aging are illustrated in Figure 6. As a rule, stocks compounded for optimum retention of *physical* properties after heat aging will also show optimum retention of *electrical* properties after heat aging.

The electrical properties of silicone rubber change very little as the temperature is increased up to 250 C (480 F). Long aging at this temperature likewise produces few changes in electrical properties (See Figure 7). When failure does occur, it is generally due to physical embrittlement—not to electrical stress.

TABLE VII—TEST EVALUATION

Tests	Typical Values for Silicone Rubber
Electric Strength (1/4-inch electrodes, rapid rise of 500 volts per second, on specimens 1/16-inch thick), volts per mil.....	450 to 600
Dielectric Constant.....	2.9 to 3.6
Dissipation Factor.....	0.0005 to 0.02
Volume Resistivity, ohm-centimeters.....	8×10^{13} to 2×10^{15}
Insulation Resistance, ohms.....	1×10^{12} to 1×10^{13}

FIGURE 6.
Electrical Properties After Heat Aging

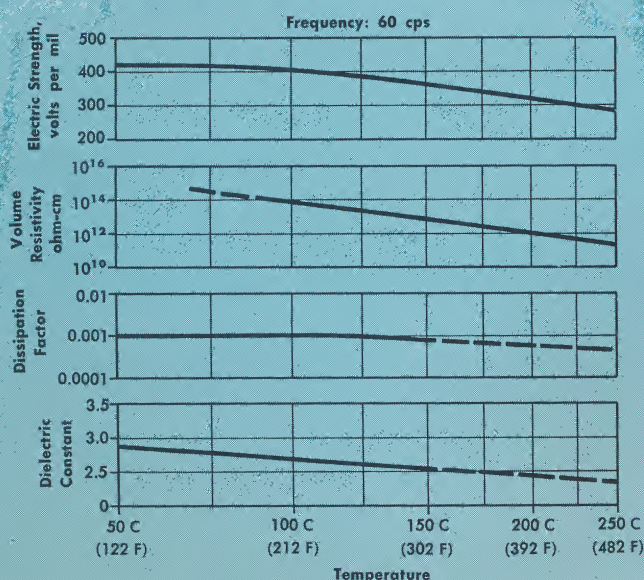
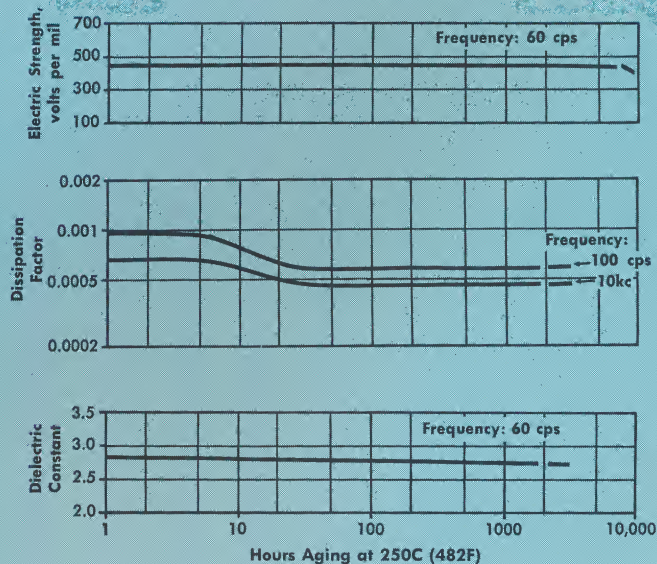


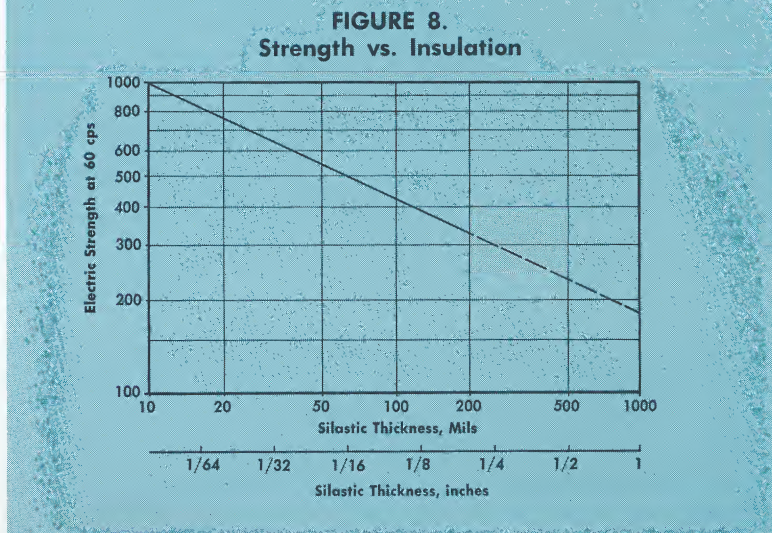
FIGURE 7.
Electrical Properties Tested
at Elevated Temperatures



Effect of Insulation Thickness on Electric Strength Value

For any electrical insulating material, the value for electric strength changes with the thickness of the test specimen. For a 10-mil sample of Silastic rubber, it is normal to expect an electric strength value of 1000 volts per mil, but if the sample is 200 mils thick, a value of 300 volts per mil might be expected, as shown in Figure 8.

These values describe the utility of general purpose silicone rubber as an insulating material. They are the means for comparing the electrical qualities of silicone rubber with other forms of insulation.



Resistance to Water and Steam

All forms of silicones are noted for their water repellency. Silicone rubber has an extremely low degree of moisture absorption, and physical properties of the rubber show little change following periods of immersion. As shown in Table VIII, this is true not only at room temperatures, but in heated and even boiling water. Superheated water will cause the rubber to break up, but only after extended, continuous immersion. Values shown in Table VIII were obtained by tests conducted on a general purpose silicone rubber.

In general silicone rubber not under pressure is little affected by moisture in the form of free steam. This is also true when the steam is at low or moderate pressures. As steam pressure increases, however, the effects upon properties of silicone rubber become greater. As a general rule, Silastic silicone rubber stocks are not recommended for long-term service in applications where the steam pressure will exceed 50 pounds. Test values in Table IX were measured on the same type of general purpose silicone rubber stock as used in the water immersion testing.

TABLE VIII—PROPERTIES VS. WATER IMMERSION

<i>Immersion Conditions</i>	<i>Swell, Percent</i>	<i>Hardness Change, Shore A Scale Points</i>
7 days at 77 F.....	+1	-1
7 days at 158 F.....	+1	-3
7 days at 212 F.....	+1	-5
1 day at 250 F.....	+5	-6
3 days at 250 F.....	+6	-6
1 day at 350 F.....	+15	-16
3 days at 350 F.....	— — Broke Up — —	

TABLE IX—PROPERTIES VS. STEAM CONTACT

<i>Contact Conditions</i>	<i>Swell, Percent</i>	<i>Hardness Change, Shore A Scale Points</i>
14 days at 5 psi.....	+3	-5
14 days at 10 psi.....	Nil	-5
14 days at 20 psi.....	+4	-8
3 days at 50 psi.....	+2	-4
7 days at 50 psi.....	+9	-17
1 day at 100 psi.....	+3	-8
7 days at 100 psi.....	+13	-35

TABLE XIII—MIL-R-5847D

Class	Hardness	SILASTIC Rubber Stock Recommendation
Ia (Low Temperature)	40	S6565U
	50	651 or S6560U
	60	651 and 675 Blend
	70	651 and 675 Blend
	80	675
Ib (Low Temperature and Low Compression Set)	40	S6565U
	50	651
	60	651 and 675 Blend
	70	651 and 675 Blend
	80	675
IIa (High Temperature)	40	241
	50	52 or 745U
	60	8-164 or 746U
	70	50 and 80 Blend or 747U
	80	80, 82 or 748U
IIb (High Temperature and Low Compression Set)	40	241
	50	S-2248 or 745U
	60	S-2096U or 746U
	70	S-2097U or 747U
	80	S-2098U or 748U
III (Tear Resistance)	25	S-6557U
	50	950U
	60	960U
	80	80 or 82

TABLE XIV—
MIL-R-25988,
AMENDMENT II

Hardness	SILASTIC Rubber Stock Recommendation
55 to 75	LS-53
	LS-63

Bonding Silicone Rubber

Designers who need to fasten a finished part made of silicone rubber in place have no problem because the product can be bonded to metal, glass, ceramics, silicone-glass laminates or to itself.

Surfaces other than silicone rubber should be treated with a suitable primer before bonding. These can be applied by wiping, spraying, or brushing. When applied, these primers are hydrolyzed by moisture from the air in about 30 minutes.

Primers

Dow Corning A-4094 primer prepares surfaces for bonding with Silastic S-2200 adhesive, fluorosilicone rubber stocks, Silastic 950U rubber, Silastic 140 adhesive, and Silastic 142 fluorosilicone adhesive.

Dow Corning A-4014 primer prepares surfaces for bonding Dow Corning A-4000 adhesive.

Dow Corning 796 primer prepares surfaces for bonding with most unvulcanized Silastic compounds.

Chemlok 607, a product of Hughson Chemical Company, like Dow Corning 796 primer, prepares surfaces for bonding with most unvulcanized Silastic stocks. Apply according to the manufacturer's directions.

Adhesives

Most Silastic rubber stocks can be bonded to themselves or to metals by simply molding the unvulcanized stock in contact with a properly prepared surface. However, to bond vulcanized or fully cured stocks, Dow Corning offers a complete line of heat vulcanizing or room temperature curing adhesives. Several such products are described in the following paragraphs.

Silastic S-2200 adhesive and Silastic S-2234U rubber are heat vulcanizing, solventless silicone rubber materials. Both give strong, rubbery bonds serviceable over a wide temperature span.

Silastic 140 adhesive and Silastic 732 RTV rubber are solventless silicone rubber pastes that vulcanize at room temperature on exposure to moisture in the air. The adhesives will bond silicone rubber parts to such surfaces as etched Teflon, neoprene, wood, paper, masonry or almost anything else. Bonds are strong, rubbery, and serviceable from -70 to 400 F.

Dow Corning A-4000 adhesive is a 2-part, solvent-containing silicone adhesive that cures at room temperature to give good bond strength. Properly cured bonds are serviceable from -70 to 500 F.

Silastic 142 fluorosilicone adhesive is a solventless paste that vulcanizes on exposure to moisture in the air. It is used for bonding fluorosilicone rubber parts to metal and other surfaces.

Finished Parts Made of Silicone Rubber

Silastic® silicone rubber can be processed into finished parts on standard rubber-working equipment. Thus, a variety of forms and shapes are available to the design engineer. Seals of almost any profile are extruded and sliced into the desired thickness. Simple and complex shapes are molded. Glass or other types of fabric coated with thin films of silicone rubber can be produced by calender coating or by coating from a solvent dispersion of silicone rubber. Ducts and hose are made by wrapping silicone-rubber-coated cloth on mandrels. By incorporating blowing agents, silicone rubber sponge can be produced.

Many Silastic silicone rubber compounds are white, clear, or lightly colored, so they can be pigmented to almost any color desired. In short, the design engi-

neer can specify elastomeric parts made from Silastic silicone rubber and be sure of a source for evaluation and production parts. Over 150 rubber companies produce such parts, and many of them stock sheet, rod, tubing and O-rings as off-the-shelf items.

A list of these manufacturers is available from Dow Corning. Those making general rubber parts are listed in the bulletin "Manufacturers of Parts Made From SILASTIC Silicone Rubber". Tape and coated cloth manufacturers are listed in a bulletin titled "Manufacturers of Tape Made With SILASTIC Silicone Rubber".

For information about Silastic brand silicone rubber address requests to: Engineering Products Division, Dow Corning Corporation, Midland, Michigan 48641.

DOW CORNING